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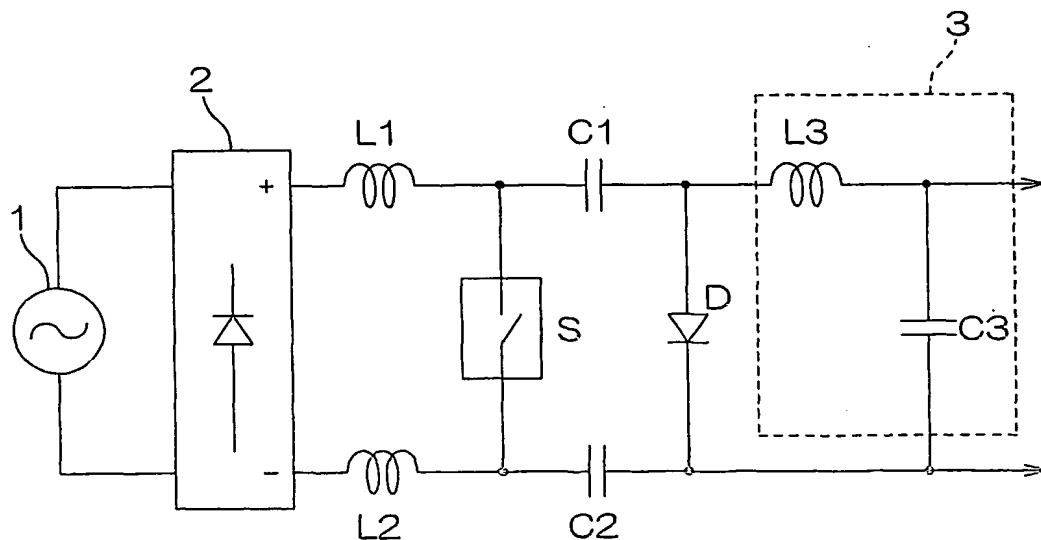
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- (75) Inventor/Applicant (for US only): WANG, Guo-Hua For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: CUK CONVERTER WITH INDUCTORS AND CAPACITORS ON BOTH POWER LINES



(57) Abstract: Inductors L1, L2 are respectively inserted in series at the positive and negative sides of lines for guiding a direct current supplied from an alternating current power supply 1 through a rectification circuit 2, or a direct current supplied directly from a direct current power supply, a switching element S is connected in parallel to the inductors L1, L2, and capacitors C1, C2 are respectively inserted in series between the positive-side inductor L1 and a load, and between the negative-side inductor L2 and the load. Even no transformer is used, not only insulation for a direct current but also insulation for an alternating current can sufficiently be ensured (Figure 1).

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## DESCRIPTION

CUK CONVERTER WITH INDUCTORS AND CAPACITORS ON BOTH POWER  
LINES

## BACKGROUND OF THE INVENTION

## 5 Field of the Invention

The present invention relates to a capacitor-coupled power supply apparatus.

## Description of Related Art

10 To obtain a voltage having a desired value, there are instances where a transformer is used in a power supply apparatus. Such a transformer also serves as a member for insulating the primary side from the secondary side.

On the other hand, for miniaturization and weight saving,  
15 there may be desired a power supply apparatus requiring no transformer.

Unlike in a power supply apparatus using a transformer,  
it is generally difficult in a power supply apparatus using no  
transformer to keep the insulation between the power supply side  
20 and the load side.

To keep such insulation, there is conventionally proposed  
a power supply apparatus of the type in which a capacitor is  
connected in series between the power supply side and the load  
side (Japanese Patent Laid-Open Publication No. H9-74741).

25 As a matter of fact, the power supply apparatus of the

type above-mentioned can provide insulation for a direct current, but cannot ensure a sufficient insulation for an alternating current.

In view of the foregoing, it is an object of the present invention to provide a power supply apparatus capable of assuring a sufficient insulation not only for a direct current, but also for an alternating current.

#### SUMMARY OF THE INVENTION

A power supply apparatus according to the present invention is arranged such that inductors are respectively inserted in series at the positive and negative sides of lines for guiding a direct current supplied from an alternating current power supply through a rectification circuit, or a direct current supplied directly from a direct current power supply, that a switching element is connected in parallel to the output ends of the inductors, and that capacitors are respectively inserted in series between the output end of the positive-side inductor and a load, and between the output end of the negative-side inductor and the load.

The arrangement above-mentioned is characterized in that the inductors are respectively inserted in series at the positive and negative sides of the lines for guiding a direct current.

By this characteristic, the insulation between the power supply and the load is achieved not only for a direct current

but also for an alternating current.

Preferably, the ratio in capacitance of the positive-side inductor to the negative-side inductor is a reciprocal number of the ratio in capacitance of the capacitor connected in series  
5 to the positive-side inductor, to the capacitor connected in series to the negative-side inductor.

By satisfying the relationship above-mentioned, the insulation between the power supply and the load can perfectly be achieved. Even though this relationship is not satisfied,  
10 the insulation between the power supply and the load is achieved in a practical level.

The positive-side inductor and the negative-side inductor may be the same in capacitance as each other, and the capacitor connected in series to the positive-side inductor and the  
15 capacitor connected in series to the negative-side inductor may be the same in capacitance as each other. This is the case where the ratio in capacitance above-mentioned is equal to 1.

A rectification circuit and a smoothing circuit may be connected to the output ends of the capacitors. According to  
20 the arrangement above-mentioned, there can be formed a direct-current power supply apparatus for supplying a direct-current voltage, thus further improving the insulation level.

Smoothing inductors may respectively be inserted in the  
25 positive-side and negative-side lines of the rectification

circuit. The combination of these smoothing inductors with the input-end inductors provides a smooth direct current less in pulsation.

According to the capacitor-coupled power supply apparatus of the present invention, even though a resistance is connected between the power supply side and the load side, neither a direct current nor an alternating current flows in this resistance. Accordingly, the insulation between the input side and the output side can be ensured without the use of a transformer. Thus, there can be provided a power supply apparatus suitable for a computer, a variety of communication devices and the like.

Further, according to the capacitor-coupled power supply apparatus of the present invention, the harmonic distortion given to the power transmission or distribution side is small. The resonance conditions can readily be satisfied by the inductors and capacitors, enabling noise to be absorbed. Thus, a power supply apparatus generating no noise can be provided.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic circuit diagram of a capacitor-coupled direct-current power supply apparatus according to the present invention;

Fig. 2 is a circuit diagram of a conventional capacitor-coupled power supply apparatus in which an inductor is inserted only at the positive side of a direct current after

converted;

Fig. 3 is a circuit diagram used for verifying the effect of the present invention;

Fig. 4 is a graph illustrating the voltage waveforms, with the passage of time, of the both-end voltage  $V_i$  of a resistance  $R_i$  and the load voltage  $V_L$  across the both ends of a load resistance  $R_L$  after a direct-current electricity has been turned ON in the circuit in Fig. 3;

Fig. 5 is another circuit diagram used for verifying the effect of the present invention;

Fig. 6 is a graph illustrating the voltage waveforms, with the passage of time, of the both-end voltage  $V_i$  of a resistance  $R_i$  and the load voltage  $V_L$  across the both ends of a load resistance  $R_L$  after a direct-current electricity has been turned ON in the circuit in Fig. 5;

Fig. 7 is a circuit diagram of a direct current power supply apparatus of prior art; and

Fig. 8 is a graph illustrating the voltage waveforms, with the passage of time, of the both-end voltage  $V_i$  of a resistance  $R_i$  and the load voltage  $V_L$  across the both ends of a load resistance  $R_L$  after a direct-current electricity has been turned ON in the circuit in Fig. 7.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following will discuss in detail an embodiment of the

present invention with reference to attached drawings.

Fig. 1 is a schematic circuit diagram of a capacitor-coupled direct-current power supply apparatus according to the present invention.

5        An alternating current voltage of a commercial alternating current power supply 1 is converted into a direct (pulsating) current by a first rectification circuit 2. Inductors L1, L2 are respectively inserted at the positive and negative sides of the converted direct current, and a high frequency switch  
10    S is connected in parallel to the output sides of the inductors L1, L2.

      Further, capacitors C1, C2 are respectively connected to the inductors L1, L2, and a diode D forming a second rectification circuit is connected to the output sides of the capacitors C1,  
15    C2. Connected to the output side of the diode D are an inductor L3 and a capacitor C3 which form a smoothing circuit 3.

      The capacitances of the inductors L1, L2 and the capacitances of the capacitors C1, C2 have a relationship according to the following equation (1):

20        
$$L1/L2 = C2/C1 \dots\dots\dots (1)$$

      As a special case, this relationship includes a relation of  $L1=L2$  and  $C1=C2$ .

      Fig. 2 is a circuit diagram of prior art in which an inductor L1 is inserted only at the positive side of a direct current  
25    after converted, and in which no inductor is inserted at the



negative side. The arrangement of other circuit elements is the same as that of Fig. 1.

As shown in Fig. 1, the present invention is arranged such that the inductor L1 is disposed at the positive side of a direct current, that the inductor L2 is disposed at the negative side of the direct current, and that the capacitances of the inductors L1, L2 and the capacitances of the capacitors C1, C2 satisfy the equation (1) above-mentioned, thus achieving both a direct-current insulation and an alternating-current insulation between the power supply and the output of the smoothing circuit 3.

This can be proven, as will be later discussed in Examples, by making sure that neither a direct-current electricity nor an alternating-current electricity flows in a resistance connected between the power supply and the output side of the smoothing circuit 3.

In the foregoing, an embodiment of the present invention has been discussed, but the present invention should not be limited to this embodiment. For example, the present invention can also be applied to a direct-current input type power supply apparatus having neither the alternating current power supply 1 nor the first rectification circuit 2. Further, the present invention can also be applied to an alternating-current input type power supply apparatus which is not provided with the first rectification circuit 2 and which is connected directly to the

alternating current power supply 1. Further, the present invention can also be applied to an alternating-current output type power supply apparatus with both the diode D and the smoothing circuit 3 omitted. Besides, various modifications may also be made within the scope of the present invention.

<Example 1>

Fig. 3 is a circuit diagram used for verifying the effect of the present invention. The circuit arrangement and the circuit constants were entered into a computer and the voltages and current waveforms of respective parts were estimated with the use of a circuit analyzing software.

The circuit in Fig. 3 is of the direct-current-input and direct-current-output type, and the alternating current power supply 1 and the first rectification circuit 2 in Fig. 1 are omitted. There are used coils of  $15\mu\text{H}$  as members corresponding to the inductors L1, L2, and capacitors of  $0.01\mu\text{F}$  as members corresponding to the capacitors C1, C2. Accordingly, this circuit satisfies the relationship of  $L1=L2$  and  $C1=C2$ . The chopping frequency is 200 kHz.

A resistance of  $20\Omega$  is connected as a load  $R_L$ . Connected to one end of the load  $R_L$  is a resistance  $R_i$  to be used for investigating the insulation.

Fig. 4 is a graph illustrating the voltage waveforms, with the passage of time, of the both-end voltage  $V_i$  of the resistance  $R_i$  and the load voltage  $V_L$  across the both ends of the load

resistance  $R_L$  after a direct-current electricity has been turned ON.

In Fig. 4, the voltages  $V_L$ ,  $V_i$  on the axis of ordinate are shown in volt, while the time on the axis of abscissas is shown in  $\mu\text{sec}$ .

As shown in the graph in Fig. 4, the load voltage  $V_L$  quickly rises up after the power has been turned ON, but the voltage  $V_i$  remains substantially zero. Accordingly, the insulation between the input and output sides is ensured.

10      <Example 2>

Fig. 5 is another circuit diagram used for verifying the effect of the present invention. There are used coils of  $10\ \mu\text{H}$  and  $20\ \mu\text{H}$  as members respectively corresponding to the inductors  $L_1$  and  $L_2$ , and capacitors of  $0.014\ \mu\text{F}$  and  $0.007\ \mu\text{F}$  as members respectively corresponding to the capacitors  $C_1$  and  $C_2$ . Accordingly, this circuit satisfies the relationship of  $L_1/L_2 = C_2/C_1 = 0.5$ .

Fig. 6 is a graph illustrating the voltage waveforms, with the passage of time, of the both-end voltage  $V_i$  of a resistance  $R_i$  and a load voltage  $V_L$  after a direct-current electricity has been turned ON.

As shown in the graph in Fig. 6, likewise in Fig. 4, the load voltage  $V_L$  quickly rises up after the power has been turned ON, but the voltage  $V_i$  remains substantially zero.

25      <Comparative Example>

Fig. 7 is a circuit of prior art. In this circuit, a coil of  $30\mu\text{H}$  is inserted only at the positive side of the direct current power supply. Capacitors of  $0.01\mu\text{F}$  are used as done in Example 1.

5        Fig. 8 shows the voltage waveforms, with the passage of time, of the both-end voltage  $V_i$  of a resistance  $R_i$  and a load voltage  $V_L$  after a direct-current electricity has been turned ON in the circuit in Fig. 7. It is understood from the graph in Fig. 8 that a large high frequency voltage of frequency  $200\text{kHz}$   
10    is being superposed on the both-end voltage  $V_i$  of the resistance  $R_i$ .

Accordingly, the insulation for an alternating current is not sufficient. If the resistance  $R_i$  is a human body, a high frequency electric current flows in the human body, causing the  
15    same to receive an electric shock.

## CLAIMS

1. A capacitor-coupled power supply apparatus characterized in that:

5 inductors are respectively inserted in series at the positive and negative sides of lines for guiding a direct current supplied from an alternating current power supply through a rectification circuit, or a direct current supplied directly from a direct current power supply;

10 capacitors are respectively inserted in series between the positive-side inductor and a load, and between the negative-side inductor and the load; and

a switching element is connected between the coupling point of the positive-side inductor with the capacitor connected in series thereto, and the coupling point of the negative-side inductor and the capacitor connected in series thereto.

2. A capacitor-coupled power supply apparatus according to Claim 1, wherein the ratio in capacitance of the positive-side inductor to the negative-side inductor is a reciprocal number of the ratio in capacitance of the capacitor connected in series to the positive-side inductor, to the capacitor connected in series to the negative-side inductor.

25 3. A capacitor-coupled power supply apparatus according

to Claim 2, wherein the positive-side inductor and the negative-side inductor are the same in capacitance as each other, and the capacitor connected in series to the positive-side inductor and the capacitor connected in series to the negative-side inductor are the same in capacitance as each other.

4. A capacitor-coupled power supply apparatus according to Claim 1, wherein a rectification circuit and a smoothing circuit are connected to the output ends of the capacitors.

10

5. A capacitor-coupled power supply apparatus according to Claim 4, wherein smoothing inductors are respectively inserted in the positive-side and negative-side lines of the rectification circuit.

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FIG. 1

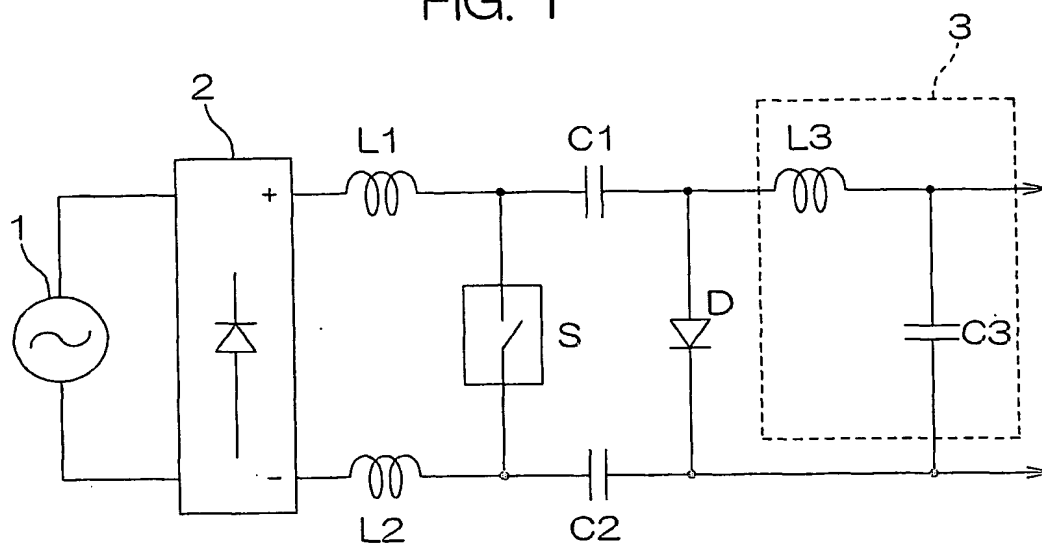
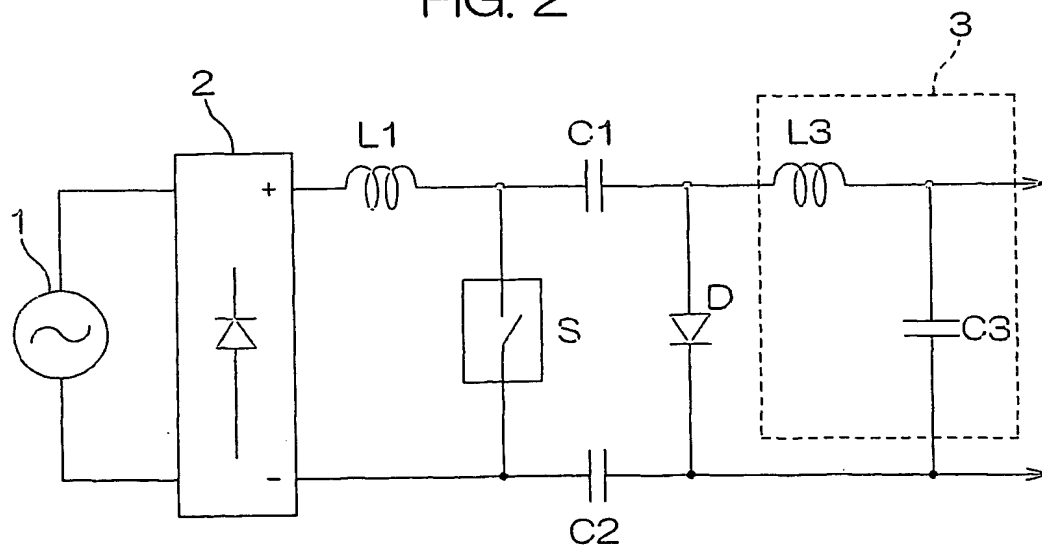


FIG. 2

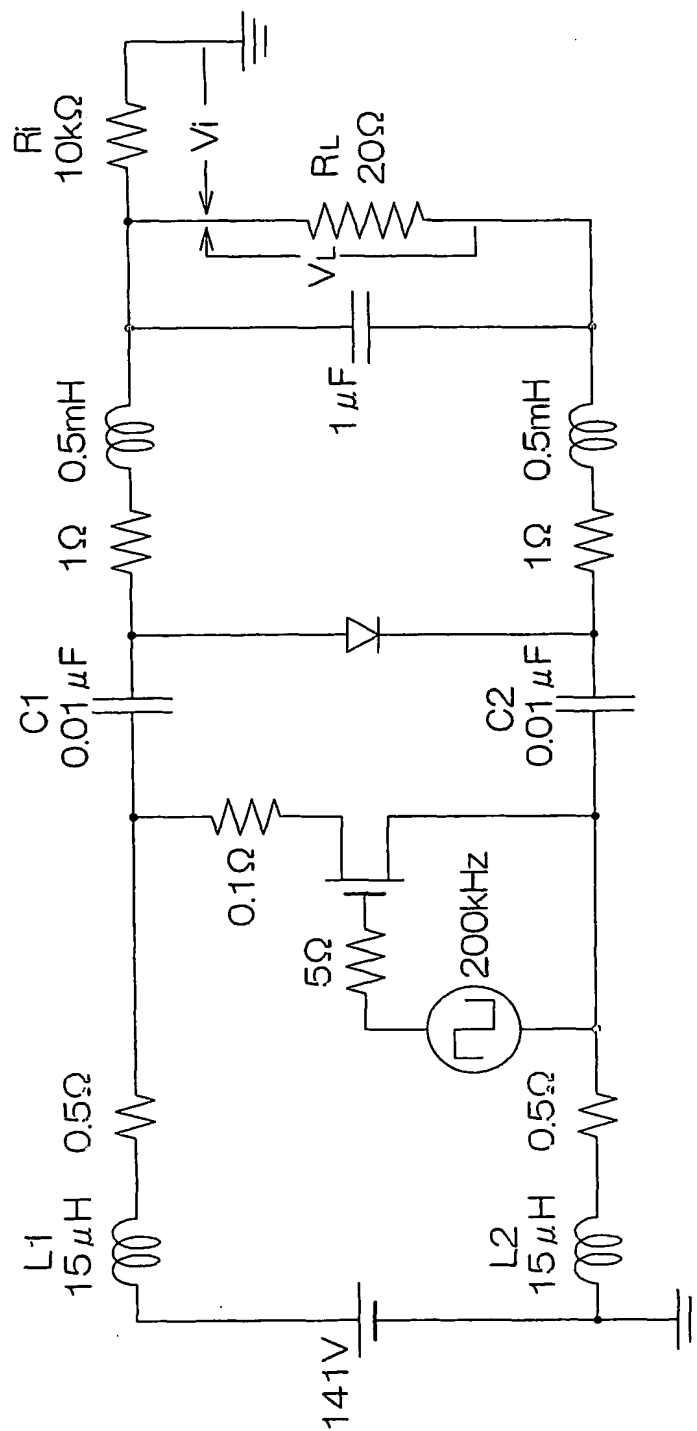


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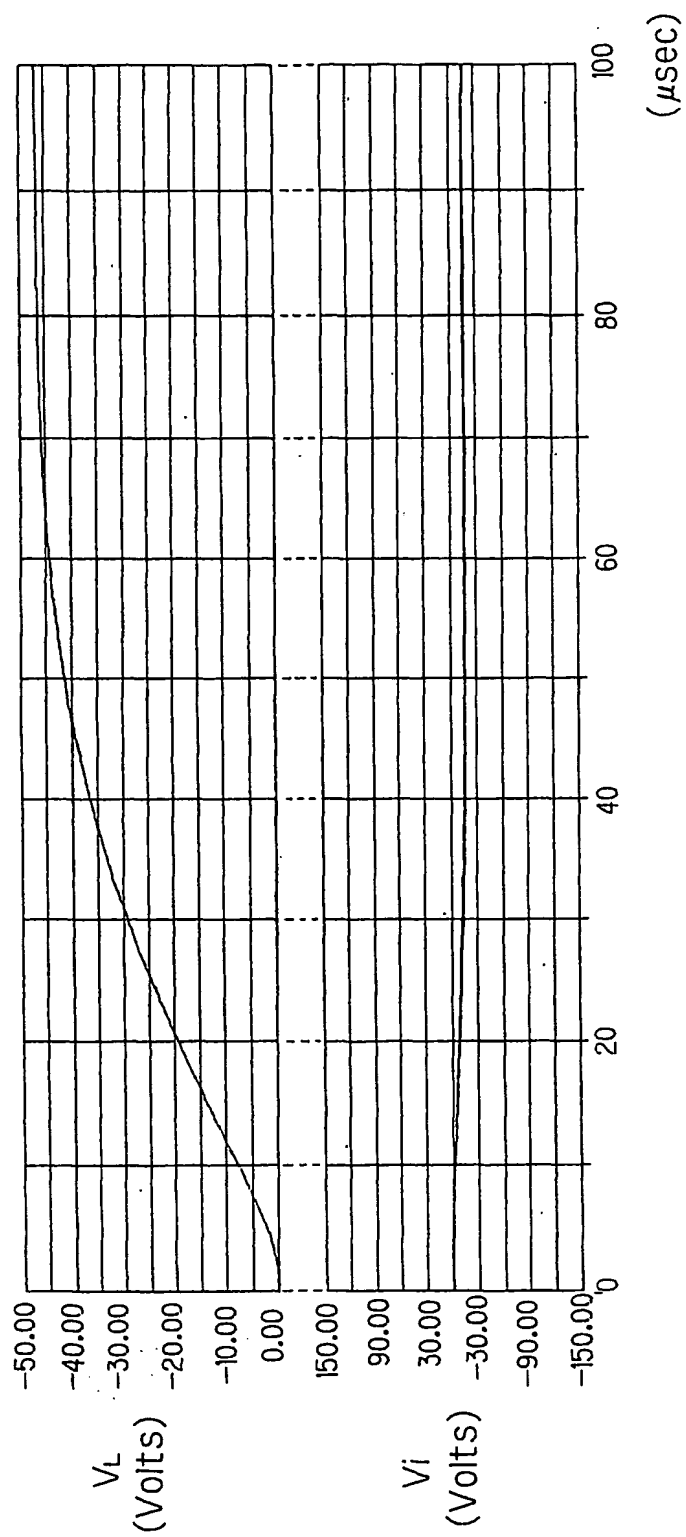
FIG. 3



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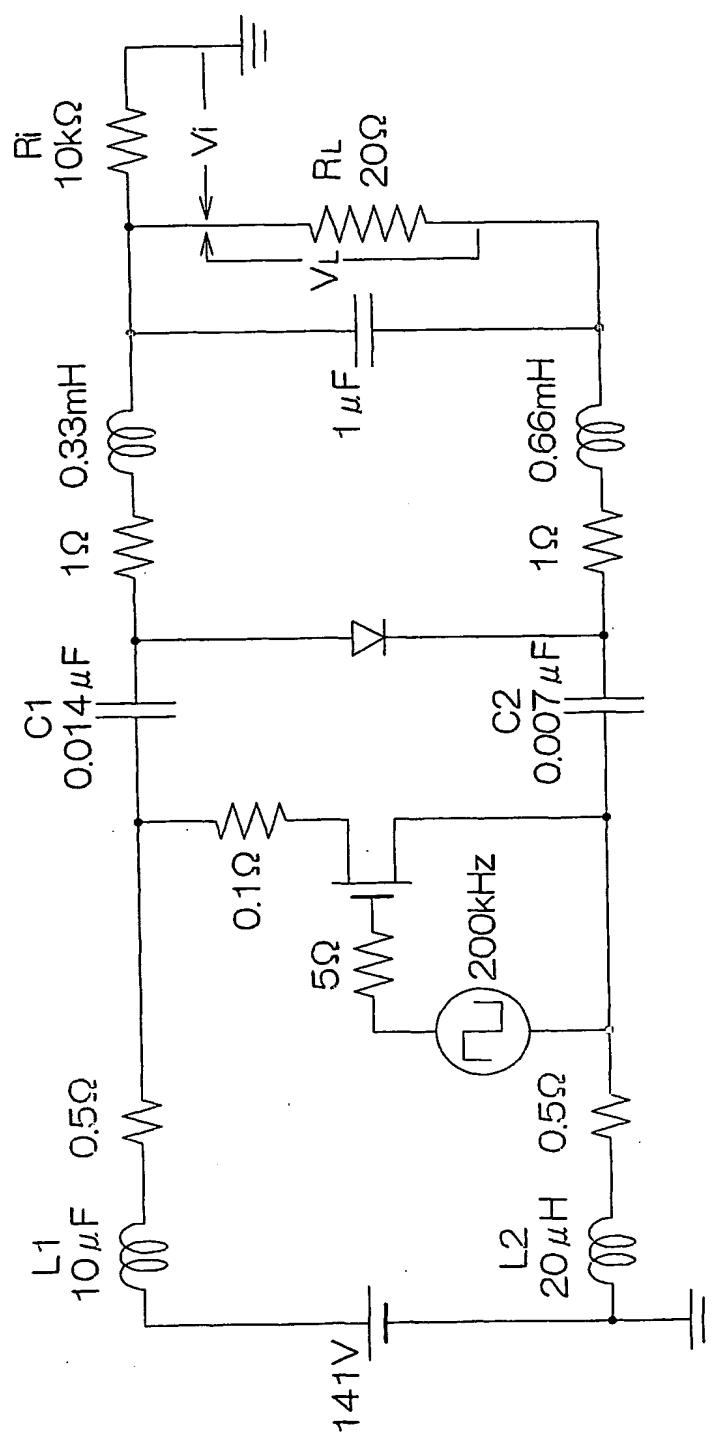
FIG. 4



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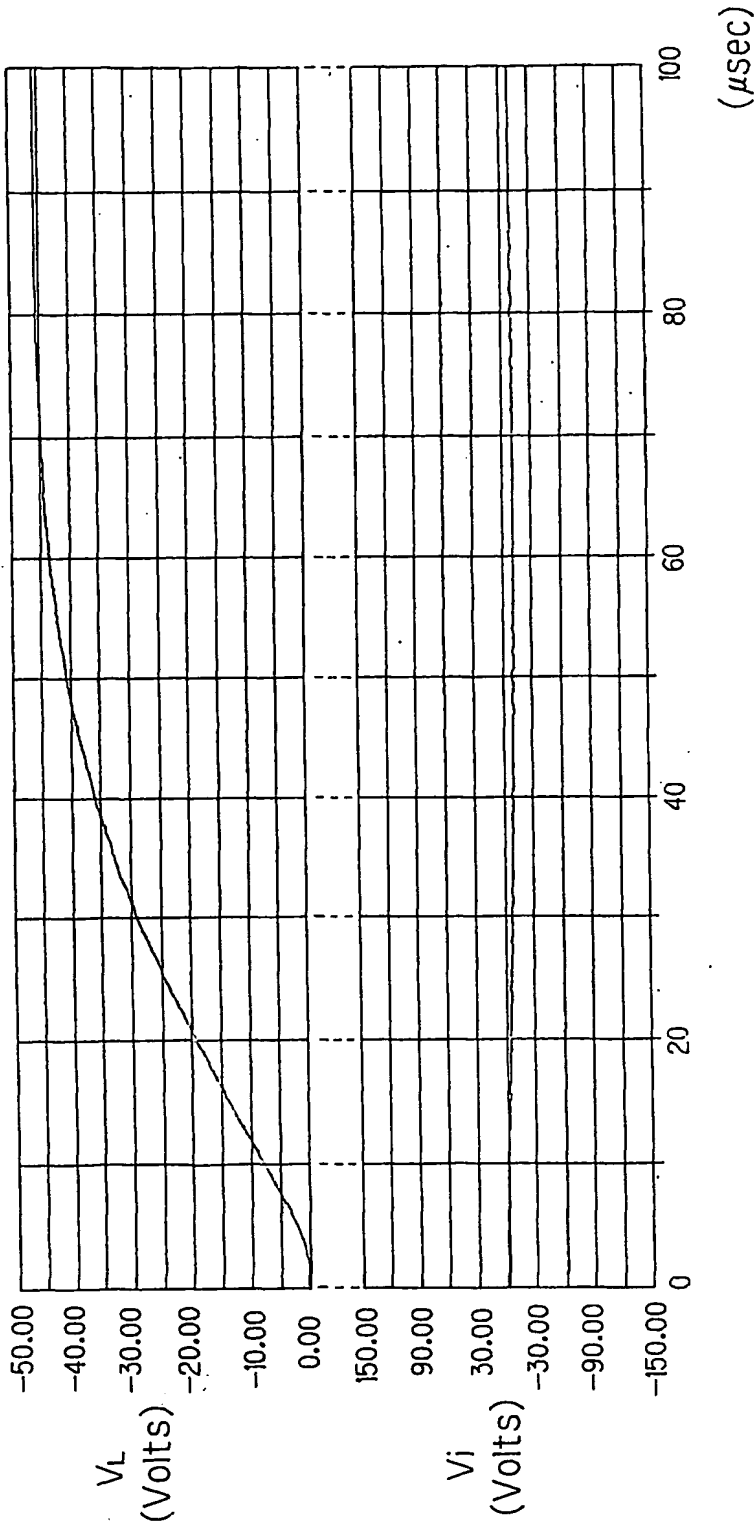
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FIG. 5



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FIG. 6

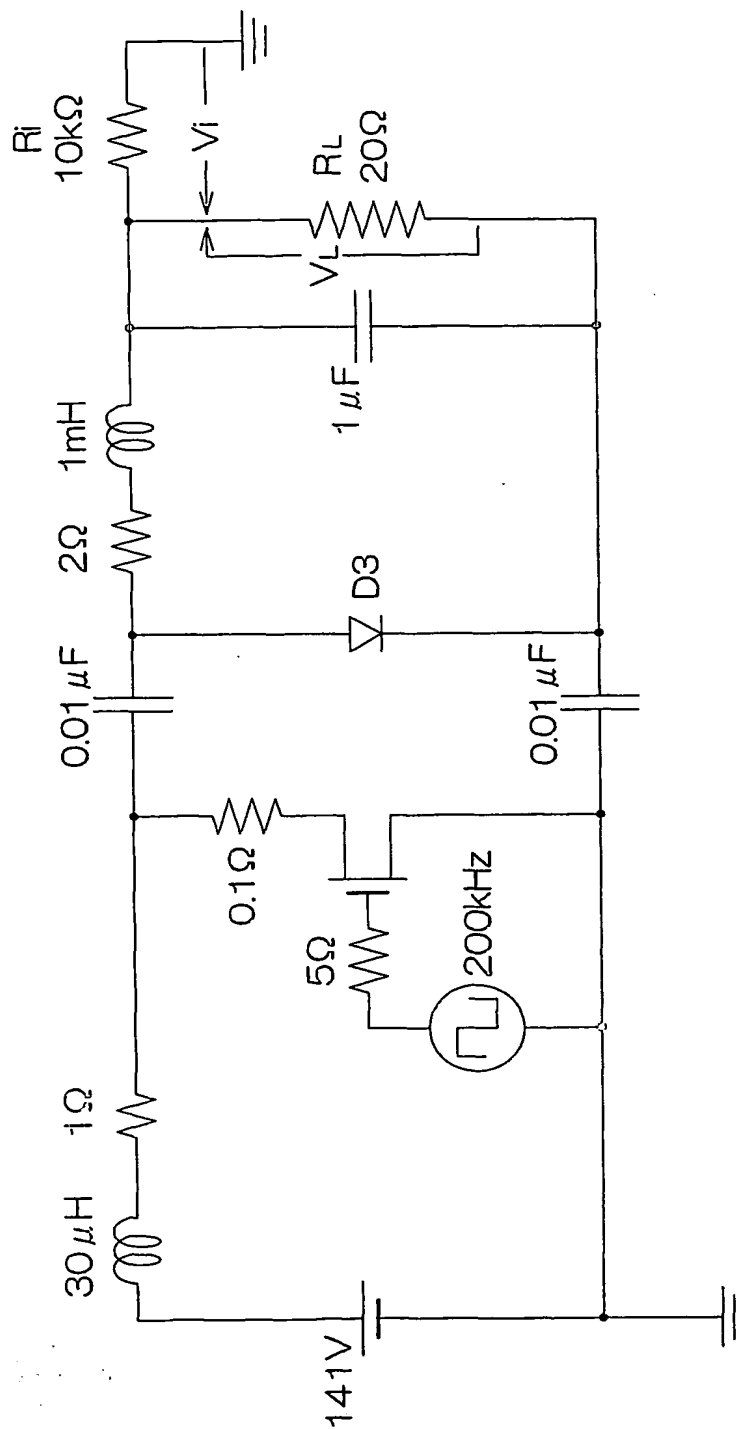


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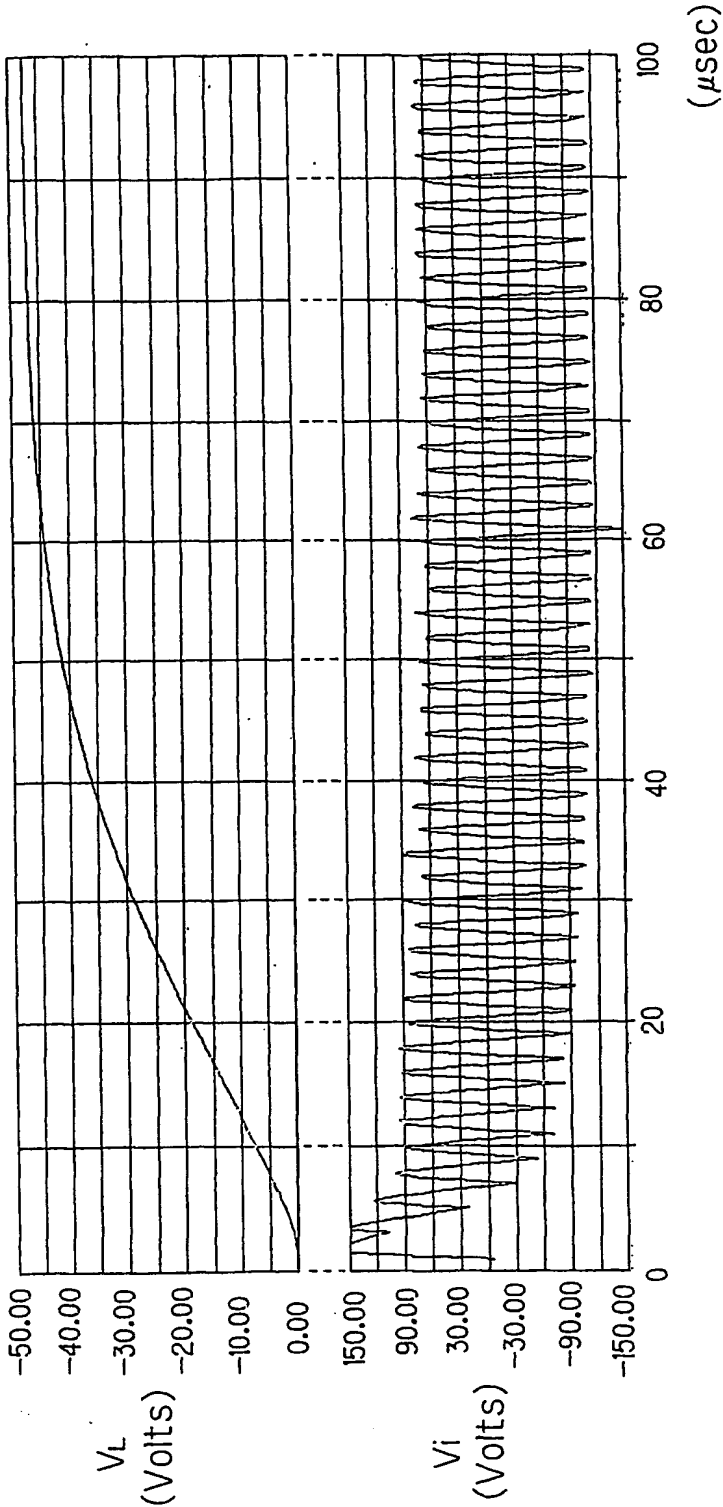
FIG. 7



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FIG. 8



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# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/JP 03/00972

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 H02M3/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 H02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 635 175 A (PROBST HARALD) 6 January 1987 (1987-01-06) column 3, line 1 - line 3; figure 2 column 4, line 54 - line 68	1-5
X	US 6 144 565 A (LETHELLIER PATRICE R) 7 November 2000 (2000-11-07) column 3, line 1 - line 3; figures 4; 11 column 5, line 1 - line 3 column 3, line 38 - line 39	1-5

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

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Date of the actual completion of the international search

30 October 2003

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/JP 03/00972

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4635175	A	06-01-1987	DE 3369445 D1 EP 0087593 A2	26-02-1987 07-09-1983
US 6144565	A	07-11-2000	NONE	